TRANSNAV
http://www.transnav.eu
the International Journal
on Marine Navigation
and Safety of Sea Transportation
Volume 8
Number 2
June 2014

DOI: 10.12716/1001.08.02.13

An Expert System for Supporting the Design and Selection of Mechanical Equipment for Recreational Crafts

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ABSTRACT: Expert Systems can be defined as computer programs, whose main task is to simulate a human expert, usually in a narrow field of expertise. Expert Systems have experienced tremendous growth and popularity since their commercial introduction in the early 1970's. Today, Expert Systems are used in business, science, engineering, manufacturing and other engineering applications such as planning, scheduling, diagnosing equipment failures and are used in almost every stage of the manufacturing process and also in medicine and many other fields. Expert Systems belong to the field of artificial intelligence. An intelligent computer program that uses knowledge and inference procedures to solve problems that are difficult enough to require significant human expertise for the solution. The purpose of this paper is to present an Expert System which assists with the design of yachts and supports the selection of mechanical equipment for yachts and includes knowledge in the field of yachting engineering. Using the presented Expert System reduces the time during the design and production preparation process.

1 INTRODUCTION

What is an Expert System?

An Expert System is a computer program that emulates the decision making ability of a human expert. The term emulates means that the Expert Systems are intended to act in all respects like human expert. Emulation is much stronger that a simulation, which is only required to act like the real thing in some respects [1].

An Expert System makes extensive use of specialized knowledge to solve problems at the level of a human expert. A human expert is a person who has experience in a certain area. That is, the expert has knowledge or special skills that are not known or available to most people. An expert can solve problems that most people cannot solve at all or solve them much more efficiently.

The knowledge in Expert System systems may be either expertise or knowledge that is generally available from books, magazines and knowledgeable persons.

Expert Systems are capable of computational, qualitative, descriptive and explanatory functions.

An additional advantage of Expert Systems is the ease of use, in a process which boils down to a series of questions and answers between the computer program and the user, in which the system receives relevant information, not only from the user but also from external sources of knowledge, such as spreadsheets, and other calculation tools [1].

In yacht building, the time required for the production of an individual boat has got less importance than a focus on extremely high quality, providing exceptional comfort and luxury to the

owner and his or her guests with state of the art furnishings and equipment. This equipment will include electronic and hydraulic systems providing the ability to control and maneuver the vessel in adverse conditions with a little or no stress and with a very small crew.

Very often the reputation of the boat building company is the determining factor in setting the boat's final price and producing the order to proceed with design completion and construction.

A common practice of boat manufacturers is to select individual items of equipment from recommendations in catalogs, which may well be weighted to specify all items to be "safe" in terms of strength and power output, but which may also be unnecessarily heavy and expensive. This has the potential for increasing the final cost of the yacht, and in some cases such as diesel engines for bringing about premature failure as a result of excessive low power and low temperature operation.

It is typical for inland yachts that often are used small diesel and petrol engines.

Conversely, selecting under-sized or under-powered components will lead to frequent breakdowns, early replacements, and in extreme situations, may endanger the lives and safety of the people on the vessel.

Yacht manufacturing costs are also greatly affected by excessive expenditures for labor to install over-sized equipment, well intended to ensure the safety of the yacht and ensure the comfort of its use. A fully developed Expert System will help to choose, customize and calculate the required materials and equipment for safety, comfort and cost control. In other words, the information provided by such an expert system may affect all costs, causing the final product of the to be much lower while maintaining the desired comfort and capabilities required in the completed yacht. In addition, the use of this Expert System will mean that production will be smooth and efficient.

2 ABOUT EXPERT SYSTEMS

An Expert System is a computer program, which contains knowledge about a specific and usually narrow field. The system has a capability to solve problems comparable with that of a human expert in the same field of knowledge – it is a computer software designed to solve problems that require specialized knowledge. Expert Systems belong to the field of artificial intelligence, which is the study of issues including fuzzy logic, evolutionary computation, neural networks, artificial life and robotics. Artificial intelligence is a branch of computer science, the object of which is to study the rules of human behavior and intelligence, to create formal models of that behavior and human thought processes and, as a result, to create computer programs that simulate the behavior and intellect of humans [2].

The starting point to development of the Expert System is analysis of the process of preparation of production [3].

The main idea is to create programs, which, when knowledge and reasoning techniques are introduced, can generate answers similar to those that would be provided by a highly experienced or educated – experience is nit equal to engineering or design knowledge human being. In effect, you will use the system to access the human expert's knowledge and experience through the user interface of the computer or other device running the program. The user of this service asks questions and receives answers and explanations presented in various forms, such as: text, video, sound, photo, figure, scheme [3].

2.1 *Advantages of Expert Systems (Why not to try to link that with yacht design)*

- Increased availability. Expertise is available on any suitable computer hardware. An Expert System can be considered to be a mass production of expertise.
- Reduced cost. The cost of providing expertise per user is greatly lowered.
- Reduced danger. Expert Systems can be used in environments that may be considered hazardous to a human.
- Permanent. The expertise is permanent. Unlike human experts who might retire, quit or die. (not fully true- equipment and engineering solutions do have own life and can be replaced by new products, software needs updating or conversions as the computers can fail to work – i.e could be dead as well)
- Multiple expertise. The knowledge of multiple experts can be made available to work simultaneously and continuously on a problem day or night.
- Increased reliability. Expert Systems increase confidence that the correct decision was made by providing a second opinion to a human expert or break a tie in case of disagreements by multiple human experts.
- Explanation. The Expert System can explicitly explain in detail the reasoning that led to a conclusion. A human however may be too tired, or unwilling or unable to do this all the time. This can increase the confidence that the correct decision was undertaken.
- Fast response. Fast or real-time response may be necessary for some applications. depending on the software and hardware used, an Expert System may respond faster and is more readily available than a human expert.
- Steady, unemotional, and complete response at all times. This may be very important in real time and emergency situations when a human may not operate at peak efficiency because of stress or fatigue.
- Intelligent database Expert Systems can be used to access a database in an intelligent manner.
- Intelligent tutor. The Expert System may act as an intelligent tutor by letting the student run sample programs and explaining the system's reasoning [4].

2.2 *Disadvantages of Expert Systems*

- Answers may not always be correct. Experts often make mistakes, so it can be expected that Expert Systems will also make mistakes. These errors could be quite costly at times.
- Knowledge limited to the domain of expertise. Expert Systems always endeavor to deduce a solution, regardless of whether or not the problem at hand is within the system's field of expertise. They have limited knowledge of what they know and when they know it. As a result of this misleading or incorrect answers may be generated, which an unsuspecting user may take as fact. A human expert, in contrast, will know the limits of their abilities and knowledge, and as a result they will not try to solve problems outside of their expertise.
- Lack of common sense knowledge can be difficult to represent in expert systems. Some measure of common sense can be represented but it must be done explicitly.
- Expert Systems can provide an excellent approach for solving a large class of problems, but each application must be chosen carefully so this technology is appropriately applied [4].

2.3 *Expert Systems in Manufacturing*

Expert Systems have been used in manufacturing for a wide variety of applications. Expert Systems have been used in manufacturing automation for a number of years. The initial systems developed by the research community or by early adopters of the technology provided some significant paybacks and created an initial enthusiasm for the technology. Expert Systems have a great deal of opportunities for implementation into manufacturing, such as scheduling and forecasting, simulation, process modeling, and resource allocation, diagnostics, process control and planning, quality and safety, pricing, packaging, and customizing. These areas can all be divided up again so there are hundred's of possibilities out there for any type of manufacturing [5].

3 STRUCTURE AND DESCRIPTION OF THE PRESENTED EXPERT SYSTEM WHICH CAN BE USED AS A SUPPORT OF YACHT MANUFACTURING PROCESSES

Recreational craft, to which Expert Systems can be applied, include sailing yachts, displacement-hull motor boats and planning motor boats.

The inspiration to create such a system is the fact that the Polish market does not contain too much detailed literature describing problems in design of yachts, engineering production of yachts. There is no Expert System supporting the yacht design and manufacturing process. There is a strong demand for materials presenting practical knowledge in field of yacht design and manufacturing but so far, no Expert System has been developed in Poland, and perhaps the world, to assist in that design and production process – no yacht designer or manufacturer in Poland uses such software.

The described Expert System has been built as an application of the PC-Shell computer tool, an independent tool for construction of Expert Systems [6]. It combines various methods of solving problems and knowledge representation. It can be used in any field, hence the range of its applications is very wide. The PC-Shell is mainly predisposed to solve the problems of the diagnostic and classification and interpretation of data [6].

Using Expert Systems boils down to the supply of facts or other information to the Expert System where, on this basis, the expert answer is presented [6].

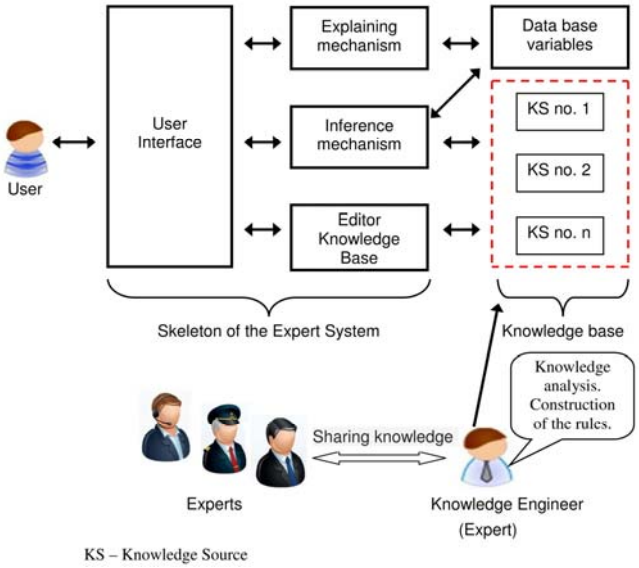

Figure 1. Schematic diagram of the presented Expert System

3.1 *Knowledge base (yacht design and construction)*

A knowledge base contains facts and rules which are necessary to solve the problem in a specific field. The facts are sentences that mean for example: sailing vessel has a length of 15 meters. This fact can be represented as a relationship between certain objects and characterized with different features. Besides it in the knowledge base can be other objects such as displacement for motor boats or planning-hull power boats.

An important feature of the system is the possible of parameterization of the knowledge bases. With this solution the dynamic changes of selected values (parameters) in the knowledge base, take place without any changes in the source code of the base [7]. A good example of the application of parameterization mechanism can be a knowledge base in which we test some values of some indicators such as how to choose the correct bow and stern thruster for the vessel depending on the length of the hull at the water line. At the same time, some threshold values can be variable, depending on the case. For example, you can evaluate several different indicators of a boat depending on its destination [7].

3.2 *Data base (knowledge sources)*

The described Expert System has been built as an application of the PC-Shell, which is a hybrid system of array architecture. With such a structure, to solve the problems, it can utilize multiple knowledge sources [7].

Typical knowledge source in the system of the array architecture is a knowledge base. In the presented Expert System we can use any number of knowledge sources.

A reference to the sources of knowledge can be made in the main program (control block) by using the appropriate instructions. It is also possible to use the same knowledge source by many different applications that use it to solve the same problem [7].

The presented Expert System includes sources of knowledge in the field of engineering yachting. The program has the following knowledge sources such us: marine diesel engines, stern gear systems, exhaust systems, fuel systems, fresh water systems, waste water systems, maneuvering systems, hydraulic steering systems, anchoring systems [7].

3.3 *Data base variables*

It is an (auxiliary) data base that stores the conclusions obtained by the system during its operation. This data base allows you to reconstruct how inference system works and present it to the user (by means of) the explaining mechanism [7].

3.4 *Editor knowledge base*

This editor allows you to modify the knowledge contained in the system, thanks to this, extension of the Expert System is possible [7].

3.5 *Inference mechanism*

The task of the inference module is to solve problems by using the knowledge contained in the knowledge base. For this purpose we use appropriate inference procedures. The current version of the system provides only backward chaining [7].

Backward chaining often takes the form of verification of hypotheses, it proceeds from the rules to the facts. In practice, this is done in such a way that the system tries to agree the hypothesis with a factor a rule(facts take precedence). If they fail to agree the system searches the next fact or the rule, and repeates surgery consultation. The system is fitted with are currence. It provides, inter alia, finding all the available solutions of a certain problem [7].

3.6 *Explaining mechanism*

This mechanism allows, at the user's request, to explain why such a system gave no other answer, or why a system asked you a specific question

This system provides four kinds of explanations: “How?", "Why? ",“What it is?" and a metaphor [7].

3.7 *User interface*

The user uses the system by communicating with it through the user interface, which is used to communicate with the program. The user asks questions, provides information and receives answers and explanations which can be presented in various forms, such as text, video, audio, image, drawing, diagram [7,8].

In addition, the presented system includes module calculations, such as calculation of the theoretical maximum speed of the displacement hull , the choice of engine power for the boat, the choice of water lock, calculation of the force acting on the steering wheel, thruster power selection, calculation of the maximum pull of the windlass.

4 KNOWLEDGE BASE DESCRIPTION OF THE PRESENTED EXPERT SYSTEM

The presented Expert System displays a knowledge of the following subjects:

1 Calculation of the theoretical maximum speed of displacement boat
2 Engine and around the engine
  – the engine power calculator for displacement boats
  – the engine power calculator for planning boats
  – calculator for selection of a water lock
  – cooling system
  – fuel system
  – wet exhaust system
  – engine assembly – Movie
3 Stern gear systems
  – construction of the drive line
  – selection of the diameter of the drive shaft
  – selection of the numbers of bearings supporting the drive shaft
  – selection of the type of coupling
4 Transmissions (This part refers to gearboxes and couplings)
  – Technodrive (US/German manufacturer of water craft drives used also in yachts)
  – ZF (ZF Marine Srl in Padova – pleasure crafts eqp manufacturer)
  – and many others
5 fresh water system (should include a potable water system – for selection of desalinator)
6 waste water system (sanitary water piping)
7 power hydraulic steering system
  – single steering position
  – dual steering position
  – dual steering position + autopilot
  – calculation of the force acting on the rudder with balance section
  – calculation of the force acting on the rudder without balance section
8 maneuvering system
  – selection of thrusters (bow thruster and stern thruster)
  – movie – assembly thruster in a yacht
9 anchoring systems
  – selection of the weight of the anchor
  – selection of a windlass

Is there selection of batter procedure – vast part of equipment is driven by electricity)

An Expert System is designed in such a way that it is easy to enter a new source of knowledge into the system, that is for example, together with the development of technology, the knowledgeable engineer can enter new information into the system.

5 AN EXPERT SYSTEM PRESENTATION

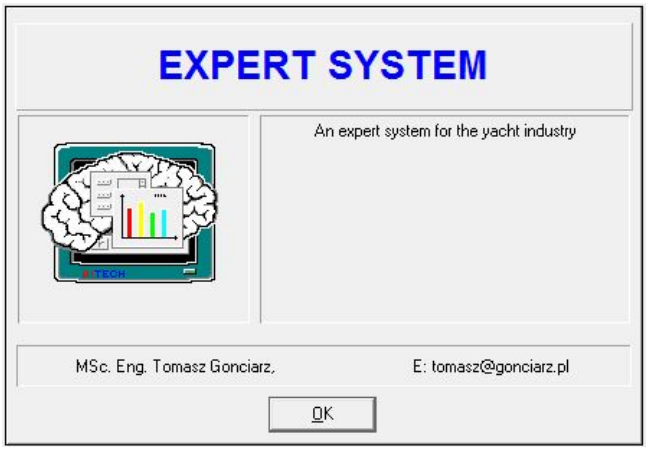

Figure 2. The Expert System welcome screen

Figure 3. Main Menu of dialog box

In Fig. 3 is a view the Main Menu functions. The user selects a tab with a problem whose solution is looking for.

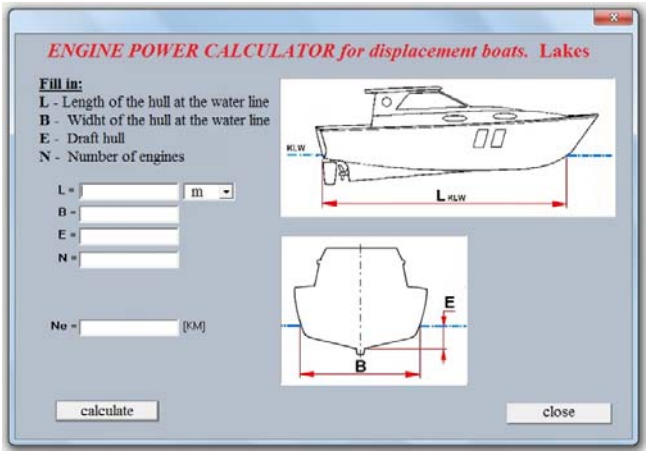

Figure 4. The Engine Power Calculator of dialog box

In Fig. 4 a view of the function which enables the calculation of the required engine power for the boat is shown. The user selects from the Main Menu functions "Engine power calculator" and enters values such as the length and width of the hull at the water line, draft and number of engines. After clicking the Calculate button the required engine power for the boat N_e is returned.

Figure 5. The windlass selection calculator of dialog box

Fig. 5. What pull capability of windlass will I need?

The only meaningful way to rate anchor winch performance is by looking at what it will lift and at what speed. The two things to consider are:
- the maximum pull capability
- the working load of the winch

Maximum pull (sometimes referred to as stall load) is the maximum short term or instantaneous pull of the winch. Working load is generally rated about a third of the maximum pull and is usually considered to be the load that the winch is pulling once the anchor is off the bottom. To determine your required maximum pull capability, complete the calculation above. Fill in: D – chain wire diameter, L1 – chain length, L2 – rope length, C – weight of the anchor. And after clicking the Calculate button the result is the maximum pull.

6 ASSESSMENT OF THE PRESENTED EXPERT SYSTEM

The assessment of the Expert System in terms of its construction, usefulness, accuracy has been divided into two stages, through which an objective evaluation has been made.

First step. Rating the knowledge base.

The knowledge base is the foundation of the Expert System. It contains facts and rules that are necessary to solve the problem in the field. Knowledge that is stored in the form of rules, was subjected to a detailed assessment of six experts. The experts assessed the correctness of constructed rules and stored facts in terms of its content.

Assessment by the experts included all of the rules stored in the knowledge base.

To obtain high-quality of the knowledge base they used the following assumptions. If the rule obtains less than 70% of the average of all evaluations of the respondents, then the rule is discarded from the source of the knowledge and replaced with another one, that is also subjected to evaluation.

Second step. The Expert System was tested in three independent companies in the marine industry.

The selected staff responsible for testing the Expert System is a group of experts and specialists who, on a daily basis, work in manufacturing, in pre-production, and as designers and technicians are responsible for the assembly process.

Responses obtained from the Expert System were checked and compared with the professional literature by the people who tested the program.

The system was found to be a highly useful program due to its following characteristics:
- easy to find information
- interface transparency
- speed of responses
- the program includes extensive knowledge.

The tested Expert System has helped to shorten the pre-production phase of the manufacturing process and resulted in a dramatic reduction in final vessel costs by optimizing the selected equipment package. It has made a unique contribution to manufacturing efficiency.

7 CONCLUSIONS

The Expert System is a comprehensive guide to engineering and manufacturing yachts applications.

Emphasizing the basic concepts and procedures, it focuses not only on the technology but also on how to select, initiate, implement and manage of technology.

This Expert System presents guidelines ranging from problem selection, data analysis, validation, integration, implementation and maintenance. People who will use the presented Expert System can work more efficiently.

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